

Regions, innovation systems, and the North-South divide in Italy

Loet Leydesdorff; Ivan Cucco

How to cite this article:

Leydesdorff, Loet; Cucco, Ivan (2019). "Regions, innovation systems, and the North-South divide in Italy". *El profesional de la información*, v. 28, n. 2, e280214.
<https://doi.org/10.3145/epi.2019.mar.14>

Article received on 07 April 2019
Approved on 16 April 2019



Loet Leydesdorff ✉
<https://orcid.org/0000-0002-7835-3098>

Amsterdam School of Communication
Research (ASCoR), University of Amsterdam
PO Box 15793, 1001 NG Amsterdam, The
Netherlands
loet@leydesdorff.net



Ivan Cucco
<https://orcid.org/0000-0003-3768-1236>

Graduate School, The American University of
Rome
Via Pietro Roselli 4, 00153 Roma RM, Italy
i.cucco@aur.edu

Abstract

Innovation systems are not bound by administrative or political boundaries. Using information theory, we measure innovation-systemness as synergy among size-classes, postal addresses, and technological classes (NACE-codes) of firm-level data collected by Statistics Italy at different scales. Italy is organized in twenty regions, but there is also a traditional divide between the North and the South of the country. At which levels is how much innovation-systemness indicated? The greatest synergy is retrieved by considering the country in terms of Northern and Southern Italy as two sub-systems, with Tuscany included as part of Northern Italy. We suggest that separate innovation strategies could be developed for these two parts of the country. The current focus on regions for innovation policies may to some extent be an artifact of the statistics and EU policies. In terms of sectors, both medium- and high-tech manufacturing (MHTM) and knowledge-intensive services (KIS) are proportionally integrated in the various regions

Keywords

Innovation systems; Innovation policies; Triple helix; Synergy; Regions; Administrative boundaries; Economic divide; Italy.

1. Introduction

The concept of national innovation systems was first proposed by Freeman (1987) after a visit to Japan. In the years thereafter, Lundvall (1993) and Nelson (1993) provided two collections of comparative studies of innovation systems among nations. However, the emphasis on "national" more or less provoked the question of whether innovation systems might also be regional. On the one side, regions such as Catalonia, Flanders, and Wales have autonomous aspirations. At the level of the European Union, on the other side, the metaphor of an emerging "knowledge-based economy" rapidly became more popular than a focus on nations (Foray; Lundvall, 1996; Commission of the European Community, 2000).

Both the EU and the OECD provide incentives for organizing regional innovation agencies and programs. Among other things, the OECD reviews regional innovation policies with the objective of providing policy recommendations (e.g., OECD, 2009). In innovation studies and economic geography, it is increasingly assumed that regions

Both the EU and the OECD provide incentives for organizing regional innovation agencies and programs

Acknowledgment

We thank Federica Rossi, Daniele Rotolo and anonymous referees for comments on a previous version.

(including metropolitan regions) are the appropriate units of analysis for studying the transition to a knowledge-based economy (e.g., **Braczyk; Cooke; Heidenreich**, 1998; **Cooke**, 2002; **Feldman; Storper**, 2016; **Florida**, 2002; **Storper; Kemeny; Makarew; Osman**, 2015).

For the purpose of implementing innovation policies at the appropriate level, it is important to understand the complexity and boundaries of innovation systems. **Griliches** (1994) noted that the use of administrative units in statistics can be a data constraint for innovation studies and also for innovation policies. For example, innovation may depend on interactions and infrastructures that do not match regional and national boundaries (**Carlsson; Stankiewicz**, 1991). Sectorial innovation systems (e.g., oil refinery; biotechnology) are in important respects organized internationally (**Carlsson**, 2006; 2013).

“Innovation may depend on interactions and infrastructures that do not match regional and national boundaries”

Malerba (1993, at p. 230) argued that “not one, but two innovation systems are present in Italy:”

- The first one is a “core R&D system” that operates at the national level through systematic cooperation between large firms with industrial laboratories, small high-tech firms, universities, public research institutes, and the national government.
- The second innovation system would be a “small-firms network” composed of a plurality of small- and medium-sized firms that cooperate intensively at the local level, often within industrial districts, and generate incremental innovation through learning-by-doing.

More generally, it has been shown that firms interact with non-regional universities if the knowledge and skills required are not available within the region (**Asheim; Coenen**, 2006; **Fritsch; Schwirten**, 1999) or when they are seeking higher-quality collaboration partners at the international level (**D’Este; Iammarino**, 2010; **Laursen; Reichstein; Salter**, 2011).

Notwithstanding these international ramifications, one can expect the coherence of an innovation system to be a mixture of both national and regional aspects given the organization of the political systems. The research question then becomes: how much innovation-systemness is generated at the various levels? Is this innovation-systemness distributed across regions or specialized in specific regions? The synergy measure used in this paper enables us to address these questions empirically. We focus on Italy as a challenging and exemplary case: to what extent and at which level is innovation-systemness indicated? Can the regions carry the function of “regional innovation organizers” (**Etzkowicz; Klostén**, 2005)? In other words, we test whether regional innovation systems are indicated using entropy statistics.

2. The Italian innovation system

Italy was shaped as a nation state in the period 1848-1870. During the Second War of Independence (1859-1861), the northern part was unified under the leadership of the Kingdom of Piemonte (Turin), and the southern part —the Kingdom of the Two Sicilies (with Naples as capital)— was conquered by Garibaldi. Central Italy, which until then had been the Papal State, was invaded by Italy in 1870 and thereafter Rome became the capital of the nation. The division into three parts —Northern, Central, and Southern Italy— has, however, remained important; it is commonly used for analytical and policy purposes. However, the North/South divide is also a common terminology in political discourse: the “questione meridionale” or the Southern Question. In short, the North and the South have different cultural traditions and marked differences in GDP per capita, composition of economic activities, and employment indicators.

At a lower level of aggregation, the country is administrated in terms of twenty regions of which five have a special status. Among these, Valle d’Aosta is an autonomous region, in which French functions as a second language. Alto Adige (also known as Süd-Tirol) is an autonomous province of Trentino-Alto Adige, bordering on Austria, with German as a second language. Below the level of regions, 107 provinces are defined in the statistics.¹ Furthermore, Italy is known for its “industrial districts” which often cover a small territory within one or more provinces, with specialized manufacturing or services (**Becattini et al.**, 2003; **Bertamino et al.**, 2017). These districts are highly innovative and mainly located in the northern part of the country (**Biggiro**, 1998). Using 2011 census data, *Statistics Italy (Istat)* distinguished 141 industrial districts and furthermore 611 so-called local labour systems (“sistemi locali del lavoro”, SLL) based on commuting patterns. Insofar as SLLs overlap with industrial districts, the data allows for economic analyses at the district level (e.g., **Paci; Usai**, 1999; **Mameli; Faggian; McCann**, 2008). Industrial districts, however, are not a separate level of administration and hence not included in the national statistics.

“Italy is administrated in terms of twenty regions of which five have a special status”

The regions have gained importance as innovation-policy units since 2001, when the Italian constitution was changed (*Riforma del Titolo Quinto*). A range of devolution measures gave regional governments greater control over policy areas such as health, education, and economic and industrial development, including innovation policy (**Rolfo; Calabrese**, 2006). This devolution led to a sharp reduction of the national budget for the support of industrial and R&D activities,

particularly in the South. **Brancati** (2015) estimates that between 2002 and 2013, state aid decreased by 72%; the remaining state interventions privileged Central and Northern Italy, while industrial policies in favor of the Southern regions were virtually abandoned after 2000 (**Prota; Viesti**, 2013).

Against this backdrop of devolution, the 2007-2009 economic and financial crisis has severely impacted the Italian industrial system. Compared with the trends calculated for the 1992-2008 period, about 300 bn Euro of gross investment were lost in Italy between 2008 and 2013 (**Cappellin et al.**, 2014). Southern regions were disproportionately affected: between 2007 and 2012, industrial investment in the South decreased by 47% (**Prota; Viesti**, 2013). This retreat of national policy has only partly been compensated by regional policies, supported to varying degrees by EU Cohesion and Structural funds. In the EU programs during the period 2007-2013, about 21.6 bn Euro of EU funds (*FESR/ERDF* and *FSE/EFSE*) were allocated to regions in Southern Italy for Convergence objectives (Calabria, Campania, Puglia, and Sicilia) and 6.3 bn to regions in Central and Northern Italy for Competitiveness objectives.

Despite the increasing role played by regional governments in innovation policy, it has remained a subject of debate whether the regional level is most appropriate for the design and implementation of such policies. **Nuvolari & Vasta** (2015) characterized Italy as a structurally weak national innovation system in comparison to its main competitors. The country has a weak tradition of university-industry cooperation in research and there is a lack of overall coordination in public policy and R&D support services (**Malerba**, 1993). The diverging performance between scientific and technological activities can lead to major difficulties in the technology transfer of scientific results from universities to firms due to a lack of bridging institutions (e.g., **Balconi et al.**, 2004).

A number of studies in various sectors of the Italian economy (e.g., **Antonioli et al.**, 2014; **Belussi et al.**, 2010; **De-Marchi; Grandinetti**, 2017; **Lew et al.**, 2018) have argued that the international orientation of research collaborations means that Italian regions cannot be considered as innovation system. These innovative regions are better characterized as “glocal” systems. They pair a relatively low connectedness at the local level with strong knowledge-intensive relationships at the international level. On the industrial side, this international orientation carries a threat of de-industrialization of innovative districts and regions because new options can easily be bought and relocated elsewhere by multinational corporations (**Cooke; Leydesdorff**, 2006; **Dei-Ottati**, 2003). The gradual emergence of knowledge production as an additional coordination mechanism in an industrial system that is otherwise coordinated in terms of institutions and markets introduces the risk of “footloose-ness” (**Vernon**, 1979). Knowledge-intensive services and high-tech manufacturing tend to uncouple an innovation system from a geographical address and can thus be counter-productive from the perspective of regional innovation policies (**https://www.scribd.com**, 2016).

Despite the increasing role played by regional governments in innovation policy, it has remained a subject of debate whether the regional level is most appropriate for the design and implementation of such policies

Register for free at <https://www.scribd.com> to download the version without the watermark

3. The systems perspective

Whereas biological systems increase uncertainty following the entropy law (**Brooks; Wiley**, 1986), technological innovation can extend the number of not-yet realized options and therewith the maximum entropy. For example, the capacity of transport across the Alps could be considered as constrained by the capacity of roads and railways such as at the Brenner Pass. As one invented new channels, however, other options became available, such as for example air transport across the Alps or tunnels underneath, which are not constrained by the conditions on the ground. An *innovation* system would not only evolve as a system —like the weather— but can also be expected to generate new options. New options add to the redundancy which is defined in Shannon’s information theory as the complement of the uncertainty to the maximum entropy.

In the case of interactions among three or more analytically different selection dynamics —market selections, technological opportunities, and strength and weaknesses because of geographical endowments (**Oh; Phillips; Park; Lee**, 2016)— mutual information among them can be positive or negative (**McGill**, 1954; **Yeung**, 2008; cf. **Krippendorff**, 2009). When *positive*, uncertainty is generated; when *negative*, the generation of redundancy —the complement of the information to the maximum entropy— prevails, and uncertainty is reduced. The three selection dynamics in that case interact as selective, but potentially overlapping and therefore redundant perspectives on the information contained in the events.

Using this generation of redundancy as an indicator of synergy, we shall show that the understanding of Italy in terms of regional innovation systems is not optimal when synergy is measured in terms of the interactions among (i) the geographical distributions of firms, (ii) the economic structure in terms of firm sizes, and (iii) the technological knowledge bases of these firms as indicated by the NACE-codes (NACE is the abbreviation for the *Nomenclature générale des activités économiques dans les Communautés Européennes*, used by the OECD and Eurostat). **Storper** (1997) has called the quality of the relations among these three dimensions —geography, technology, and organization— “a holy trinity.” This accords with the perspective of a Triple Helix of university-industry-government relations in which the dynamics of knowledge, economics, and control are combined with the objective of generating synergy.

In summary, synergy reduces uncertainty by generating new options. Reduction of uncertainty can be expected to improve the climate for investments (Freeman; Soete, 1997, pp. 242 ff.); new options provide opportunities for the survival of new activities in the highly competitive markets of emerging technologies (Bruckner; Ebeling; Jiménez-Montaño; Scharnhorst, 1996). An innovation system which no longer generates new options may increasingly be locked-in.

From the perspective of a Triple Helix of university-industry-government relations, the dynamics of knowledge, economics, and control are combined with the objective of generating synergy

4. Methods

Mutual information in relations among distributions can be measured using information theory (Shannon, 1948). First, uncertainty in the distribution of a random variable x is defined as $H_x = -\sum_x p_x \log_2 p_x$. The values of p_x are the relative frequencies of x : $p_x = f_x / \sum_x f_x$. When base two is used for the logarithm, uncertainty is expressed in bits of information. Secondly, uncertainty in the case of a system with two variables can be formulated analogously as

$$H_{xy} = -\sum_x \sum_y p_{xy} \log_2 p_{xy} \quad (1)$$

In the case of interaction between the two variables, the uncertainty in the system is reduced by mutual information T_{xy} as follows:

$$T_{xy} = (H_x + H_y) - H_{xy} \quad (2)$$

One can derive (e.g., McGill, 1954, pp. 99 ff.; Yeung, 2008, pp. 59 f.) that in the case of three dimensions, mutual information corresponds to:

$$T_{xyz} = H_x + H_y + H_z - H_{xy} - H_{xz} - H_{yz} + H_{xyz} \quad (3)$$

Eq. 3 can yield negative values of T_{xyz} and can therefore *not* be a Shannon-type information (Krippendorff, 2009). Shannon-type information measures variation, but this negative entropy is generated by next-order loops in the communication, for example, when different codes interact as selection mechanisms.

In other words, when three selective perspectives operate one another, uncertainty can be added or reduced —on top of the historical variation— by generating mutual information (with the plus sign) or redundancy (with the minus sign) depending on the configuration. Additional redundancy reduces relative uncertainty by adding options to the system. Increasing the number of options for further development may be more important for the viability of an innovation system than the options realized hitherto (Fritsch, 2004; Petersen; Rotolo; Leydesdorff, 2016).

Register for free at <https://www.scipedia.com> to download the version without the watermark

purely as a consequence of the generation of new options and output, but the investment climate as a structural consequence of *correlations* among distributions of relations. However, the distinction between these structural dynamics in terms of changing selection environments and the historical dynamics of relations is analytical: the historical and the evolutionary dynamics are coupled in the events. Eq. 3 models a trade-off between variation and selection as positive and negative contributions to the prevailing uncertainty. The question of systemness can thus be made empirical and amenable to measurement: when the generation of redundancy prevails over the generation of uncertainty, “innovation systemness” is indicated.

In the case of groups (e.g., subsamples at a lower geographical scale), one can decompose the information as follows: $H = H_0 + \sum_g n_g / N H_g$ (Theil, 1972, pp. 20 f.). The right-hand term ($\sum_g n_g / N H_g$) provides the average uncertainty in the groups and H_0 the additional uncertainty in-between groups. Since T values are decomposable in terms of H values (Eq. 3), one can analogously derive (Leydesdorff; Strand, 2013, at p. 1895):

$$T = T_0 + \sum_g n_g / N T_g \quad (4)$$

In this formula, T_g provides a measure of synergy at the geographical scale G ; n_g is the number of firms at this scale, and N is the total number of firms under study. One can also decompose across regions, in terms of firm sizes, or in terms of combinations of these dimensions.

The three dimensions are the (g)eographical, (t)echnological, and (o)rganizational; synergy will be denoted as T_{gto} and measured in millibits with a minus sign. Because the scales are sample-dependent, we normalize for comparisons across samples as percentages. After normalization, the contributions of regions or groups of regions can be compared. The between-group term T_0 (Eq. 4) provides us with a measure of what the next-order system (e.g., the nation) adds in terms of synergy to the sum of the regional systems.

A routine with further instructions is available at <http://www.leydesdorff.net/software/th4> which generates the synergy values from data which have for this purpose to be organized as comma-separated variables with for each case (that is, firm) a unique identifier, a postal code, a size class, and a NACE code. The results are organized into a file which can

be read into programs like *SPSS* or *Excel* for further processing. We use *SPSS* v.22 to generate the maps of regions in Italy on the basis of the synergy values expressed as percentages of contributions to the overall synergy of the Italian system.

5. Data and descriptive statistics

Statistics Italy (Istat) collects firm census data every ten years. In a previous study focusing on the methodology, we used this census data from 2000 for a comparison with data in the *Orbis/Amadeus* database of *Bureau van Dijk* (Cucco; Leydesdorff, 2014).² In the meantime, complete data sets for the years 2008, 2011, and 2015 have become available online from the so-called *ASIA* (*Archivio statistico delle imprese attive*) database of *Statistics Italy*. This database includes all enterprises that performed productive activities for at least six months during the reference year. However, this data does not cover the sectors agriculture, fisheries, and forestry; public administration and non-profit private organizations are also excluded. The data contain 4,514,022 firms in 2008, 4,450,937 firms in 2011, and 4,338,085 in 2015 [the 2000 industrial census data (4,247,169 firms) was organized a bit differently and therefore we use this latter data only qualitatively for the comparison].

For an analysis of synergy using the three dimensions of the Triple Helix (TH), we need three key variables:

(1) the administrative location of the firm in the form of its postal address indicating the geographical dimension (government);

(2) the *NACE* code indicating the main technology in the knowledge base of the firm, and

(3) the character of the firm in terms of its size indicated as the numbers of employees.

These three dimensions have been used in a number of previous studies about the TH in various nations (see Leydesdorff [2018] for a summary).



Figure 1. Organization of Italy into Northern, Southern, and Central Italy regions. Northern Italy is indicated in dark green, Central Italy is in very light green, and Southern Italy is in light green.

Source: figure produced by the authors using *SPSS* v. 22.

Table 1. Regional division of Italy at the NUTS 1 and NUTS 2 levels.

Codes of Istat	NUTS 1	NUTS 2	NUTS 3	NUTS 4	NUTS 5	
	(a)	(b)	(c)	(d)	(e)	
1	North-west Italy (ITC)	ITC1	Piemonte	Northern Italy	Northern Italy	
2		ITC2	Valle d'Aosta			
7		ITC3	Liguria			
3		ITC4	Lombardia			
4	North-east Italy (ITH)	ITH1 / ITH2	Trentino-Alto Adige			
5		ITH3	Veneto			
6		ITH4	Friuli Venezia Giulia			
8		ITH5	Emilia Romagna			
9	Central Italy (ITI)	ITI1	Toscana	Central Italy	Southern Italy	
10		ITI2	Umbria			
11		ITI3	Marche			
12		ITI4	Lazio			
13	Southern Italy (ITF)	ITF1	Abruzzo	Southern Italy (Mezzo-giorno)		
14		ITF2	Molise			
15		ITF3	Campania			
16		ITF4	Puglia			
17		ITF5	Basilicata			
18		ITF6	Calabria			
19	Insular Italy (ITG)	ITG1	Sicilia			
20		ITG2	Sardegna			

5.1. The geographical distribution of firms in Italy

The administrative division of Italy into Northern, Central, and Southern Italy and twenty regions is visualized in Figure 1 and further specified in Table 1. Among other things, we will test the three conventional partitions of Italy in columns *c*, *d* and *e* of Table 1.

Table 2 provides the numbers of firms in the years under study. In the right-most column we added the 2000 data used by **Cucco & Leydesdorff (2014)**, but since this data was in some respects different we use the previous study only as a point of reference. (For example, Valle d'Aosta was not counted separately in 2000.) The three data points (2008, 2011, and 2015) are sufficient to distinguish trends in the data (Figure 2).

With the exceptions of Trentino-Alto Adige and Lazio, the numbers of firms have been declining during this past decade. This confirms the impression of stagnation since the crisis of 2007-2009. Italy has only partly recovered from this crisis.

5.2. Small, medium-sized, and large enterprises

In addition to the assignment of *NACE* and postal codes, firms are scaled in terms of the number of their employees. SMEs are commonly defined in terms of this proxy. Financial turnover is also available in the data as an alternative indicator of economic structure. However, we chose to use the number of employees as one can expect this number to exhibit less volatility than turn-over, which may vary with stock value and economic conjecture more readily than numbers of employees. However, the numbers of employees are sensitive to other activities, such as outsourcing.

The definitions of small and medium-sized businesses, large enterprises, etc., vary among world regions. Most classifications use six or so categories for summary statistics. We use the nine classes provided in Table 3 because this finer-grained scheme produces richer results (**Blau; Schoenherr, 1971; Pugh; Hickson; Hinings, 1969; Rocha, 1999**).

5.3. NACE codes

The third dimension of the data to be used is the attribution of *NACE* codes. The classification of firms in terms of the *Nomenclature générale des activités éco-*

Table 2. *N* of firms in 20 Italian regions.*

Region	2008	2011	2015	(2000)*
Piemonte	344,334	339,261	323,184	335,749
Valle d'Aosta	11,959	11,933	11,257	
Lombardia	822,579	818,998	805,755	818,948
Trentino-Alto Adige	83,121	83,656	84,398	82,843
Veneto	406,800	402,976	391,474	405,952
Friuli-Venezia Giulia	88,683	86,797	82,720	89,303
Liguria	132,288	129,708	122,874	132,408
Emilia-Romagna	389,123	370,778	366,475	387,434
Toscana	338,943	332,563	320,167	337,573
Umbria	70,892	69,411	66,455	70,324
Marche	133,261	131,567	126,213	133,942
Lazio	423,059	428,715	426,322	416,460
Abruzzo	100,120	101,115	97,184	100,822
Molise	21,705	21,445	20,631	21,262
Campania	351,688	340,601	336,819	346,337
Apulia	254,431	254,277	249,196	250,264
Basilicata	36,169	35,234	34,586	35,760
Calabria	114,858	110,391	105,878	112,205
Sicily	278,451	273,155	264,480	273,903
Sardegna	111,558	108,356	102,017	108,984
	4,514,022	4,450,937	4,338,085	4,480,473

* The numbers used in the previous study are provided in the right-most column.

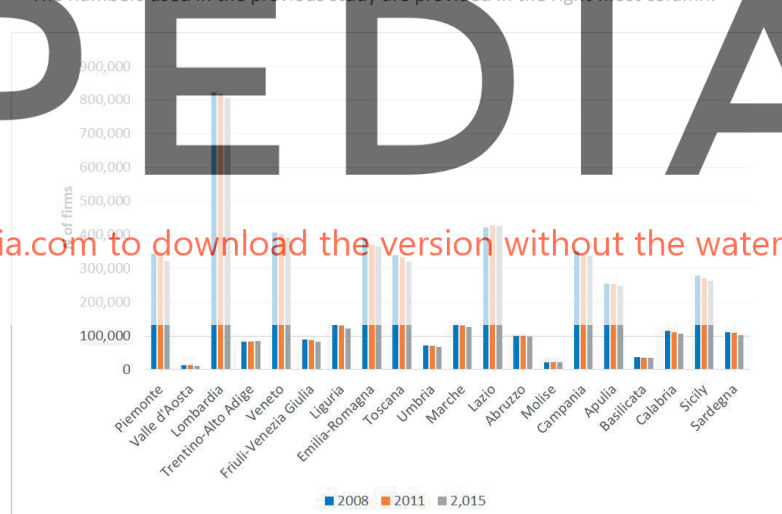


Figure 2. *N* of firms in Italian regions in 2008, 2011, and 2015. Source: *Statistics Italy*.

Table 3. Classification of firms (2015) in terms of the number of employees. Note that micro-enterprises (with fewer than five employees) constitute 91.5% of the firms under study. Source: *Statistics Italy*.

Class	N. employees	Frequency	Percent	Valid %	Cumulative %
1	0 -- 1	3,473,928	80.1	80.1	80.1
2	2 -- 4	493,365	11.4	11.4	91.5
3	5 -- 9	201,497	4.6	4.6	96.1
4	10 -- 19	99,554	2.3	2.3	98.4
5	20 -- 49	45,476	1.0	1.0	99.4
6	50 -- 99	13,275	.3	.3	99.7
7	100 -- 199	6,223	.1	.1	99.9
8	200 -- 499	3,225	.1	.1	100.0
9	500 or more	1,542	.0	.0	100.0
		4,338,085	100.0	100.0	

Table 4. NACE classifications (Rev. 2) of high- and medium-tech manufacturing, and knowledge-intensive services.

High-tech manufacturing	Knowledge-intensive sectors (KIS)
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations 26 Manufacture of computer, electronic and optical products 30.3 Manufacture of air and spacecraft and related machinery	50 Water transport 51 Air transport 58 Publishing activities 59 Motion picture, video and television programme production, sound recording and music publishing activities 60 Programming and broadcasting activities 61 Telecommunications 62 Computer programming, consultancy and related activities 63 Information service activities 64 to 66 Financial and insurance activities 69 Legal and accounting activities 70 Activities of head offices; management consultancy activities 71 Architectural and engineering activities; technical testing and analysis 72 Scientific research and development 73 Advertising and market research 74 Other professional, scientific and technical activities 75 Veterinary activities 78 Employment activities 80 Security and investigation activities 84 Public administration and defence, compulsory social security 85 Education 86 to 88 Human health and social work activities 90 to 93 Arts, entertainment and recreation
Medium-high-tech manufacturing 20 Manufacture of chemicals and chemical products 25.4 Manufacture of weapons and ammunition 27 Manufacture of electrical equipment 28 Manufacture of machinery and equipment n.e.c. 29 Manufacture of motor vehicles, trailers and semi-trailers 30 Manufacture of other transport equipment excluding 30.1 Building of ships and boats, and excluding 30.3 Manufacture of air and spacecraft and related machinery 32.5 Manufacture of medical and dental instruments and supplies	Of these sectors, 59 to 63, and 72 are considered <i>high-tech services</i> .

Sources: Eurostat/OECD (2011); cf. Laafia (2002, p. 7), and Leydesdorff et al. (2006, p. 186).

SCIPEDIA

nomiques dans les Communautés Européennes (NACE, Rev. 2) is used for indicating the technological dimension.⁴ The NACE code can be translated into the *International Standard Industrial Classification (ISIC)* that is used in the USA (e.g., Leydesdorff; Wagner; Porto-Gómez; Comins; Phillips, 2019). The disaggregation in terms of medium- and high-tech manufacturing, and knowledge-intensive services, is provided in Table 4.⁴

We will additionally analyze the subsets of high- and medium-tech companies, and (high-tech) knowledge-intensive services, because one can expect different dynamics for these sectors in contributing to synergy in the knowledge-based economy.

Register for free at <https://www.scipedia.com> to download the version without the watermark

6. Results

6.1. Regions

Figure 3 provides a visualization of the percentage contribution of the twenty regions to the national synergy of Italy in 2015. The visualizations for 2008 and 2011 are not essentially different. The rank-order correlations among the regions in these three years are significantly the same (Spearman's $\rho > .99$; $p < 0.001$).

Figure 3 shows that Tuscany belongs to the northern part of Italy as a knowledge-based economy; the distinction of Central Italy including Tuscany is not supported by this data. Mountainous regions both along the Alps and in the Apennines are weakest in generating synergy. However, one should keep in mind that Italy has a system of excellent highways and trains that cross these regions. Their relative marginality is thus not likely to be due to the mountainous character of these regions, but perhaps more a consequence of their structural positions such as their distance from metropolitan centers, harbors, and airports.

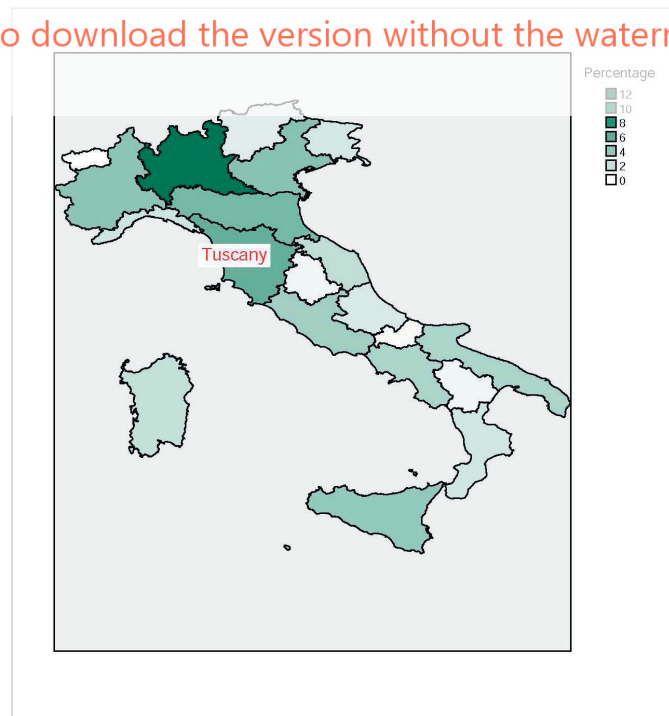


Figure 3. Percentages of contributions of the regions to the national synergy of Italy in 2015.

Figure 6 shows that the triple-helix synergy increased over time in virtually all regions (but not in Sardegna). The strongest regions became even stronger in terms of their contributions to the national synergy. For example, Lombardia increased its leading contribution to the national synergy by another 1.8%. The percentage of synergy generated above the regional level—that is, the complement to 100% of the sum of the regional contributions—declined from 48.9% in 2008 to 44.4% in 2015 (– 4.5%). This reduction of above-regional synergy contribution over time as a percentage is consistent with the progressive withdrawal of innovation policy-making at the national level, and the growing importance of the devolved regions.

In summary: regions have become more important; but only 55% of the synergy is realized at the regional level. The other 45% is realized at the above-regional level (such as NUTS1, across the North/South divide, or in Italy as a whole).

6.2. Northern, Central, and Southern Italy

Using the classification of regions into Northern, Southern, and Central Italy as provided in Figure 1 above, Figure 5 shows the above-regional synergy development using three and two classes of regions, respectively, on the right side, and the results of the twenty autonomy regions on the left side. As noted, the latter declines from 48.9 to 44.4 %. The above-regional synergy development among the *three* groups of regions (north-south-center) is of the order of 22.5%, but is not consistently increasing as the supplement of the synergy among the twenty regions. Among *two* groups of regions (North-South), however, T_0 is further reduced to 18.2% in 2015.

In other words: if Tuscany is analyzed as belonging to the northern part of the country, this part accounts for 47.0% of the synergy and the southern part for 34.9% with only 18.2% synergy at the national level. Both the northern and southern parts are more synergetic when compared with the division into three parts. Furthermore, values around 20% for the national surplus synergy were also found for other countries in previous studies. Adding Tuscany, which itself contributes only 5.8% to the synergy at the national level, to the northern part (instead of the central one), furthermore,

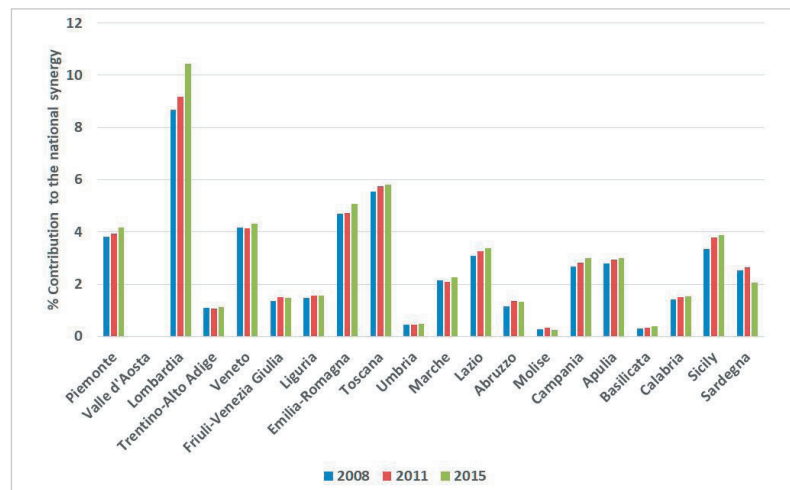


Figure 4. Percentages of contributions of the regions to the national synergy of Italy in 2008, 2011, and 2015.

Table 5. Percentages of contributions of the regions to the national synergy of Italy in 2015.

Region	2008	2011	2015
Piemonte	3.82	3.95	4.17
Valle d'Aosta	0.00	0.00	0.00
Lombardia	8.67	9.18	10.43
Trentino-Alto Adige	1.09	1.08	1.13
Veneto	4.19	4.15	4.31
Friuli-Venezia Giulia	1.37	1.51	1.49
Liguria	1.47	1.56	1.58
Emilia-Romagna	4.71	4.73	5.03
Toscana	5.55	5.75	5.81
Umbria	0.45	0.46	0.48
Marche	2.14	2.10	2.26
Lazio	3.09	3.27	3.38
Abruzzo	1.15	1.17	1.22
Molise	0.27	0.35	0.26
Campania	2.67	2.82	2.99
Apulia	2.79	2.94	3.01
Basilicata	0.32	0.33	0.38
Calabria	1.43	1.50	1.54
Sicily	3.36	3.79	3.89
Sardegna	2.54	2.66	2.07
T ₀	48.91	46.48	44.40

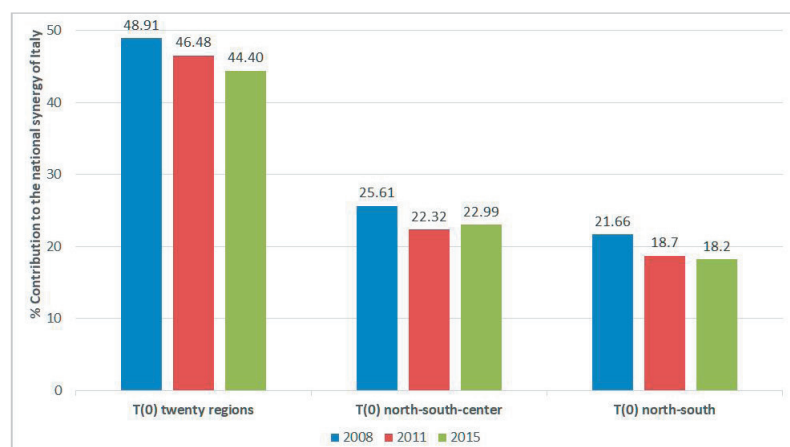


Figure 5. Above-regional synergy for Italy on the basis of 20 NUTS2-regions (left) and three macro-regions (North – South – Center).

increases the contribution of the north by more than 9% (= 46.95 – 37.90; in Table 6). Thus, an additional synergy is indicated by using this model of Italy.

The conclusion is that considering Italy as twenty regions leaves 45% of the synergy in the Italian innovation system unexplained. This is extremely high when compared with other nations. In the USA, we found that the additional synergy at the national (above-state) level is only 2.8%. This is much less than we found in previous studies of national innovation systems: Norway (11.7%), China (18.0%), the Netherlands (27.1%), Sweden (20.4%), and Russia (37.9%). Italy would score above the Russian Federation when considered in these terms, but for very different reasons (Leydesdorff, Perevodchikov; Uvarov, 2015). The high surplus in Russia is caused by the centralized nature of this system, while in Italy, the high surplus is unexplained because the wrong model is used for the country. When Italy is conceptualized as a country with two or three innovation systems, this description accords with those for other EU nations.

6.3. Sectorial decomposition

Using the NACE codes (see Table 4), we can repeat the analysis for subsets of firms which are classified as high- or medium-high tech, and knowledge-intensive services. Figures 6A and 6B show the distribution of the synergy for these subsets over the twenty regions. Of the approximately 4.3 million firms, 1,294,874 (29.8%) provide knowledge-intensive services, while only 40,083 (0.9%) are classified as MHTM in 2015. However, the differences between the distribution of the set and the subsets are marginal. Table 7 shows the rank-order correlations which are all above .95 ($p < .001$). In other words: both medium-high-tech and knowledge-intensive services are distributed proportionally over the country in terms of numbers of firms. Table 8 provides a summary of the results, including the values for these subsets as percentages of synergy in the two right-most columns.

Table 6. Percentage contributions of Northern, Southern, and Central Italy to the national synergy in 2015.

	North-Central-South	North-South
North	37.90	46.95
Center	17.50	
South	21.62	34.85
Sum	77.02	72.80
T_0	22.98	18.20
	100	100

Table 7. Rank-order correlations between the samples of firms classified as high- and medium-high-tech manufacturing (MHTM) and knowledge-intensive services (KIS) over the twenty regions of Italy.

			Full set	MHTM
Spearman's rho	Full set	Correlation Coefficient		
		Sig. (2-tailed)		
		N		
	MHTM	Correlation Coefficient	.955**	
		Sig. (2-tailed)	.000	
		N	20	
	KIS	Correlation Coefficient	.982**	.950**
		Sig. (2-tailed)	.000	.000
		N	20	20

** Correlation is significant at the 0.01 level (2-tailed).

Register for free at <https://www.scipedia.com> to download the version without the watermark

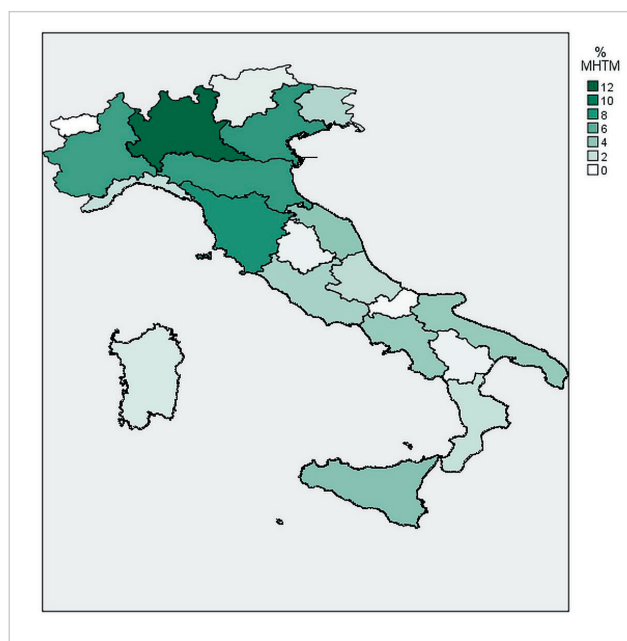


Figure 6A. Regional decomposition of the synergy in the Italian innovation system for medium- and high-tech companies

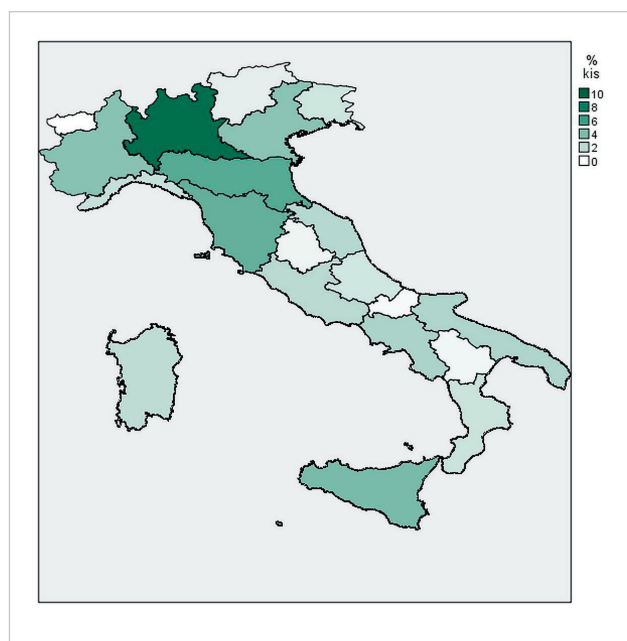


Figure 6B. Regional decomposition of the synergy in the Italian innovation system for knowledge-intensive services.

Table 8. Summary table of percentages of contributions to the synergy in the Italian innovation system (2015)

Region	2015	North_South_Center	North_South	MHTM	KIS
Piemonte	4.17	37.90	46.95	7.14	3.58
Valle d'Aosta	0.00			0.00	0.00
Lombardia	10.43			11.68	9.19
Trentino-Alto Adige	1.13			0.94	0.80
Veneto	4.31			7.66	3.54
Friuli-Venezia Giulia	1.49			2.72	1.38
Liguria	1.58			1.93	1.59
Emilia-Romagna	5.08			7.40	5.20
Toscana	5.81	17.50	34.85	8.15	4.81
Umbria	0.48			0.67	0.50
Marche	2.26			4.06	2.12
Lazio	3.38			3.07	2.07
Abruzzo	1.33	21.62		2.32	1.30
Molise	0.26			0.30	0.21
Campania	2.99			3.70	2.45
Apulia	3.01			3.76	2.36
Basilicata	0.38			0.70	0.42
Calabria	1.54			1.96	1.47
Sicily	3.89			4.44	4.09
Sardegna	2.07			1.34	1.85
Sum	55.60	77.01	71.80	73.94	48.93
T ₀	44.40	22.99	18.20	26.06	51.07

We boldfaced in Table 8 some values in the right-most columns for regions with outlier values for MHTM and/or KIS. Piemonte, Veneto, Emilia-Romagna, and Toscana have contributions to the synergy when we focus on MHTM more than two percent higher than without this focus. Lombardia, Marche, and Friuli-Venezia Giulia follow with more than one percent higher values.

Register for free at <https://www.scipedia.com> to download the version without the watermark

Unlike manufacturing, services can be offered nation-wide or even beyond the nation, and thus tend to uncouple from a specific location, leading to a negative effect on the local synergy. In Italy, this is the case mainly for services in Lombardia and Lazio, while these two regions contain the two metropolises of Milano and Rome with airports, etc. Toscana (Florence) and Veneto (Venice) follow with smaller effects.

Considering Italy as twenty regions leaves 45% of the synergy in the Italian innovation system unexplained, what is extremely high when compared with other nations

In Southern Italy, there are no effects from either MHTM or KIS. A small negative effect of MHTM is indicated for Lazio (3.07 mbits versus 3.08 for the set), probably meaning that some manufacturing may have the administrative offices in Rome without contributing to the knowledge-based synergy in this region (Lazio). Sardegna also has such a negative effect (1.34 versus 2.07; see Table 8) when focusing on MHTM because the medium- and high-tech sectors are marginal in this local economy.

7. Conclusions and discussion

7.1. Summary

Innovation systems are not *a priori* bound by administrative and political borders. In analogy to “national innovation systems” (Freeman, 1987; Lundvall, 1988; 1992; Nelson, 1993), many studies have argued for studying “regional innovation systems” such as Wales or Catalonia (Braczyk; Cooke; Heidenreich, 1998; Cooke, 1998; 2002). In our opinion, one should not make the choice between studying regions or nations on *a priori* grounds and across the board. The function of regions in an otherwise relatively homogeneous country (e.g., Denmark) is different from that in a country with a federal structure, such as Belgium.

From this perspective, Italy is an interesting case because there is a traditional divide between the north and the south, but there are also common denominators such as a single language (with small exceptions), national institu-

tions such as a network of state universities, a national research council (CNR) with a similar structure in all regions, and a central government without a federal structure. Regions have become more important during the last two decades, because of the devolution policies of the central government and the emphasis on regions in EU policies.

“ Italian regions have become more important during the last two decades, because of the devolution policies of the central government and the emphasis on regions in EU policies ”

One would expect the coherence of an innovation system to be a mixture of both national and regional aspects. The research question was: how much innovation-systemness is generated at the various levels? Is this innovation-systemness distributed across regions or specialized in specific regions? The synergy measure developed in this paper enables us to address these questions empirically.

Italy as a nation is integrated, albeit not only at the level of the twenty regions. Eight regions in Northern Italy (including Tuscany) are well developed as innovation systems. Taken together (Table 5), these eight regions contribute 34.0% to the national synergy. However, as a separate subsystem Northern Italy contributes 47.0% of the synergy (Table 6). This is 13% more than the sum of the individual regions. The regions on the northern borders with different cultural orientations (Alto-Adige and Valle d'Aosta) contribute marginally to the synergy in the northern-Italian system.

If we apply the same reasoning to Southern Italy (the Italian *Mezzogiorno*), twelve regions contribute 21.6% to the national synergy. Considered as a subsystem (Table 6), the South contributes 34.9%; that is, another 13.3% more synergy. On top of these two sub-systems, Italy as a nation contributes 18.2% to the national synergy. Thus, most synergy is found by considering Italy in terms of a northern and southern part, with Tuscany as part of Northern Italy.

The division in terms of North, South, and Central Italy relocates Tuscany into the central part. Using this model, Central Italy improves its 11.9% contribution to the national synergy to 17.5% —that is, +5.6%— while Southern Italy in this configuration improves its contribution from 15.5 to 21.6%, that is 6.1%. The seven remaining regions of Northern Italy in this case generate 28.2% of the synergy as an aggregate, but 37.9% as a single system. The additional synergy is now 9.7% and thus much less than the 13% generated additionally in the configuration of only North and South. Both Northern and Southern Italy (including Central Italy) perform better as innovation systems in terms of synergy generation in a configuration of two sub-systems (North and South). The difference is of the order of 5% synergy.

As one would expect, synergy is enhanced by focusing on high- and medium-tech manufacturing. Rome and Milano function as metropolitan centers of innovation systems, followed by Florence and the Venice region (including the harbour). Unlike Spain, where Barcelona and Madrid function as metropolitan innovation systems without much further integration into the remainder of the country (Leydesdorff; Porto-Gómez, 2019), the Italian system is well integrated in terms of MHTM and KIS.

7.2. Policy implications

If innovation policy is focused on the regional level, one may miss important opportunities in inter-regional interactions. In other words, the coordination of innovation policies among regions, particularly within each of the two major innovation (sub)systems of Italy, would be desirable. More generally, our results provide further support for the argument that administrative borders which originated for historical or administrative reasons should be examined critically in terms of their functionality for innovation systems, particularly in a knowledge-based economy which is far more networked than a political economy (Leydesdorff; Ivanova; Meyer, 2019).

The knowledge dynamics added to the economic and political dynamics generates a complex system with a volatile dynamics that tends to self-organize its boundaries (Bathelt, 2003). A complex system is resilient and thus adapts to signals that do not accord with its internal dynamics. A political administration that is not reflexively aware of and informed about how the relevant innovation systems are shaped, may miss the requisite variety to steer these systems and feel overburdened by the unintended consequences of its own actions (Ashby, 1958; Luhmann, 1997).

7.3. Limitations

The possibility to search for optima in a phase space of the three (or more) distributions may reveal growth potentials of combinations that have remained hitherto unnoticed (Rotolo *et al.*, 2017). A limitation of this study, however, remains the quality of the data. The current statistics tend to attribute a single address (for example, headquarters) to firms with multiple locations. In this study, we also used only the first NACE code of each firm. Furthermore, the sectors agriculture and fisheries were not included in the ASIA data of *Statistics Italy*, while these sectors are critical components of the economy in Southern-Italian regions.

8. Notes

1. These numbers change over time. The current count of provinces is 110.

2. Although the latter sample covered only 402,316 firms as against 4,247,169 firms in the data of *Statistics Italy*, the results at the regional level were virtually similar (Spearman's $p > .99$; $p < .001$).
3. Firms are classified in the ASIA database using *Ateco 2007* codes, the Italian version of *NACE* Rev. 2.
4. A complete index of *NACE* codes can be found, for example, at:
<http://www.cso.ie/px/u/NACECoder/Index.asp>

9. References

- Antonioli, Davide; Marzucchi, Alberto; Montresor, Sandro** (2014). "Regional innovation policy and innovative behaviour: Looking for additional effects". *European planning studies*, v. 22, n. 1, pp. 64-83.
<https://doi.org/10.1080/09654313.2012.722977>
- Ashby, W. Ross** (1958). "Requisite variety and its implications for the control of complex systems". *Cybernetica*, v. 1, n. 2, pp. 83-89.
<http://134.184.131.111/Books/AshbyReqVar.pdf>
- Asheim, Bjørn T.; Coenen, Lars** (2006). "Contextualising regional innovation systems in a globalising learning economy: On knowledge bases and institutional frameworks". *Journal of technology transfer*, v. 31, n. 1, pp. 163-173.
<https://doi.org/10.1007/s10961-005-5028-0>
- Balconi, Margherita; Breschi, Stefano; Lissoni, Francesco** (2004). "Networks of inventors and the role of academia: an exploration of Italian patent data". *Research policy*, v. 33, n. 1, pp. 127-145.
[https://doi.org/10.1016/S0048-7333\(03\)00108-2](https://doi.org/10.1016/S0048-7333(03)00108-2)
- Bathelt, Harald** (2003). "Geographies of production: growth regimes in spatial perspective 1-innovation, institutions and social systems". *Progress in human geography*, v. 27, n. 6, pp. 789-804.
<https://doi.org/10.1191/0309132503ph462pr>
- Becattini, Giacomo; Bellandi, Marco; Ottati, Gabi-Dei; Sforzi, Fabio** (2003). *From industrial districts to local development: An itinerary of research*. Cheltenham, UK / Northampton, MA: Edward Elgar. ISBN: 978 1 84376 159 4
- Belussi, Fiorenza; Sammarra, Alessia; Sedita, Silvia-Rita** (2010). "Learning at the boundaries in an 'Open regional innovation system': A focus on firms' innovation strategies in the Emilia Romagna life science industry". *Research policy*, v. 39, n. 6, pp. 710-721.
<https://doi.org/10.1016/j.respol.2010.01.014>
- Bertamino, Federica; Bronzini, Raffaello; De-Maggio, Marco; Revelli, Davide** (2017). "Regional policies for innovation: the case of technology districts in Italy". *Regional studies*, v. 51, n. 12, pp. 1826-1839.
<https://doi.org/10.1080/00343404.2016.1255321>
- Biggiaro, Lucio** (1998). "Italian industrial districts: a Triple Helix pattern of problem solving". *Industry and higher education*, v. 12, n. 4, pp. 227-234.
<https://doi.org/10.1177/095042229801200408>
- Blau, Peter M.; Schoenherr, Richard A.** (1971). *The structure of organizations*. New York: Basic Books. ISBN: 978 0 465082407
- Braczyk, Hans-Joachim; Cooke, Philip; Heidenreich, Martin** (eds.). (1998). *Regional innovation systems*. London / Bristol PA: University College London Press. ISBN: 978 0 415303699
- Brancati, Raffaele** (ed.) (2015). *Le strategie per la crescita. Imprese, mercati, governi*. Rapporto MET 2015, Donzelli Editore. ISBN: 978 88 6843 230 0
- Brooks, Daniel R.; Wiley, Edward O.** (1986). *Evolution as entropy*. Chicago/London: University of Chicago Press. ISBN: 978 0 226075815
- Bruckner, Eberhard; Ebeling, Werner; Jiménez-Montaño, Miguel A.; Scharnhorst, Andrea** (1996). "Nonlinear stochastic effects of substitution —an evolutionary approach". *Journal of evolutionary economics*, v. 6, n. 1, pp. 1-30.
<https://doi.org/10.1007/BF01202370>
- Cappellin, Riccardo; Marelli, Enrico; Rullani, Enzo; Sterlacchini, Alessandro** (2014). "Introduzione: linee guida per il rilancio della politica industriale e regionale". In: Cappellin, R.; Marelli, E.; Rullani, E.; Sterlacchini, A. (eds.). *Crescita, investimento e territorio: il ruolo delle politiche industriali e regionali*, eBook Scienze Regionali 2014/1.
- Carlsson, Bo** (2006). "Internationalization of innovation systems: A survey of the literature". *Research policy*, v. 35, n. 1, pp. 56-67.
<https://doi.org/10.1016/j.respol.2005.08.003>

- Carlsson, Bo** (2013). "Knowledge flows in high-tech industry clusters: Dissemination mechanisms and innovation regimes". In: E. S. Andersen; A. Pyka (eds.). *Long term economic development: Demand, finance, organization, policy and innovation in Schumpeterian perspective* (pp. 191-222). Berlin / Heidelberg: Springer Verlag.
- Carlsson, Bo; Stankiewicz, Rikard** (1991). "On the nature, function, and composition of technological systems". *Journal of evolutionary economics*, v. 1, n. 2, pp. 93-118.
https://doi.org/10.1007/978-94-011-0145-5_2
- Commission of the European Community (2000). *Towards a European research area*. Brussels, 18 January 2000.
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0006:FIN:en:PDF>
- Cooke, Philip** (1998). "Introduction. The origins of the concept". In: P. Cooke; M. Heidenreich; H.-J. Braczyk (eds.). *Regional innovation systems* (pp. 2-25). London/ Bristol, PA: University College London Press. ISBN: 0 415 38369 9
- Cooke, Philip** (2002). *Knowledge economies*. London: Routledge. ISBN: 978 1 134712571
- Cooke, Philip; Leydesdorff, Loet** (2006). "Regional development in the knowledge-based economy: The construction of advantage". *Journal of technology transfer*, v. 31, n. 1, pp. 5-15.
<https://doi.org/10.1007/s10961-005-5009-3>
- Cucco, Ivan; Leydesdorff, Loet** (2014). "Measuring synergies in the Italian innovation system: A comparison of Amadeus™ and administrative data". In: 11th *Wageningen intl conf on chain and network management*, 4-6 June 2014, Capri.
- Dei-Ottati, Gabi** (2003). "Local governance and industrial districts: Competitive advantage". In: G. Beccatini; M. Bellandi; G. D. Ottati; F. Sforzi (eds.), *From industrial districts to local development: an itinerary of research* (pp. 184-209). Cheltenham, UK / Northampton, MA: Edward Elgar. ISBN: 978 1 843761594
- De-Marchi, Valentina; Grandinetti, Roberto** (2017). "Regional innovation systems or innovative regions? Evidence from Italy". *Tijdschrift voor economische en sociale geografie*, v. 108, n. 2, pp. 234-249.
<https://doi.org/10.1111/tesg.12217>
- D'Este, Pablo; Iammarino, Simona** (2010). "The spatial profile of university-business research partnerships". *Papers in regional science*, v. 89, n. 2, pp. 335-350.
https://www.academia.edu/21113133/The_spatial_profile_of_university-business_research_partnerships
- Etzkowicz, Henry; Klofsten, Magnus** (2005). "The innovating region: toward a theory of knowledge-based regional development". *R&D management*, v. 35, n. 3, pp. 243-255.
<https://doi.org/10.1111/j.1467-9310.2005.00387.x>
- Eurostat/OECD (2011). *High technology and knowledge-intensive sectors*. December 2011.
http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf
- Feldman, Maryann; Storper, Michael** (2016). "Economic growth and economic development: geographic dimensions, definitions and disparities". In: G. L. Clark, M. P. Feldman, M. S. Gertler; D. Wójcik (eds.). *The new Oxford handbook of economic geography*. Oxford: Oxford University Press. ISBN: 978 0 198755609
- Florida, Richard** (2002). "Bohemia and economic geography". *Journal of economic geography*, v. 2, n. 1, pp. 55-71.
<https://doi.org/10.1093/jeg/2.1.55>
- Foray, Dominique; Lundvall, Bengt-Åke** (1996). "The knowledge-based economy: From the economics of knowledge to the learning economy". In: *Employment and growth in the knowledge-based economy* (pp. 11-32). Paris: OECD.
- Freeman, Christopher** (1987). *Technology policy and economic performance: Lessons from Japan*. London: Pinter. ISBN: 0861879287
- Freeman, Christopher; Pérez, Carlota** (1988). "Structural crises of adjustment, business cycles and investment behaviour". In: G. Dosi, C. Freeman, R. Nelson, G. Silverberg; L. Soete (eds.). *Technical change and economic theory* (pp. 38-66). London: Pinter.
- Freeman, Christopher; Soete, Luc** (1997). *The economics of industrial innovation* (3rd ed.). London: Pinter. ISBN: 978 0 262561136
- Fritsch, Michael** (2004). "Cooperation and the efficiency of regional R&D activities". *Cambridge journal of economics*, v. 28, n. 6, pp. 829-846.
<https://doi.org/10.1093/cje/beh039>
- Fritsch, Michael; Schwirten, Christian** (1999). "Enterprise-university co-operation and the role of public research institutions in regional innovation systems". *Industry and innovation*, v. 6, pp. 69-83.
<https://doi.org/10.1080/13662719900000005>

- Griliches, Zvi** (1994). "Productivity, R&D and the data constraint". *The American economic review*, v. 84, n. 1, pp. 1-23.
<https://www.jstor.org/stable/2117968>
- Ivanova, Inga A.; Leydesdorff, Loet** (2014). "Rotational symmetry and the transformation of innovation systems in a Triple Helix of University-Industry-Government relations". *Technological forecasting and social change*, v. 86, pp. 143-156.
<http://doi.org/10.1016/j.techfore.2013.08.022>
- Krippendorff, Klaus** (2009). "Information of interactions in complex systems". *International journal of general systems*, v. 38, n. 6, pp. 669-680.
<https://doi.org/10.1080/03081070902993160>
- Laafia, Ibrahim** (2002). "Employment in high tech and knowledge intensive sectors in the EU continued to grow in 2001". *Statistics in focus: Science and technology, Theme*, v. 9, n. 4.
<https://ec.europa.eu/eurostat/documents/3433488/5504500/KS-NS-02-004-EN.PDF>
- Laursen, Keld; Reichstein, Toke; Salter, Ammon** (2011). "Exploring the effect of geographical proximity and university quality on university-industry collaboration in the United Kingdom". *Regional studies*, v. 45, n. 4, pp. 507-523.
<https://doi.org/10.1080/00343400903401618>
- Lew, Yong-Kyu; Khan, Zaheer; Cozzio, Sara** (2018). "Gravitating toward the quadruple helix: international connections for the enhancement of a regional innovation system in Northeast Italy". *R&D management*, v. 48, n. 1, pp. 44-59.
<https://doi.org/10.1111/radm.12227>
- Leydesdorff, Loet** (2003). "The mutual information of university-industry-government relations: An indicator of the Triple Helix dynamics". *Scientometrics*, v. 58, n. 2, pp. 445-467.
<https://doi.org/10.1023/A:1026253130577>
- Leydesdorff, Loet** (2018). "Synergy in knowledge-based innovation systems at national and regional levels: The Triple-Helix model and the Fourth industrial revolution". *Journal of open innovation, technology, markets, and complexity (Joltmc)*, v. 4, n. 2.
<https://www.mdpi.com/2199-8531/4/2/16/pdf>
- Leydesdorff, Loet; Dolfsma, Wilfred; Van-der-Panne, Gerben** (2006). "Measuring the knowledge base of an economy in terms of triple-helix relations among 'technology, organization, and territory'. *Research policy*, v. 35, n. 2, pp. 181-199.
<https://doi.org/10.1016/j.respol.2005.09.001>
- Leydesdorff, Loet; Fritsch, Michael** (2006). "Measuring the knowledge base of regional innovation systems in Germany in terms of a Triple Helix dynamics". *Research policy*, v. 35, n. 10, pp. 1538-1553.
<https://doi.org/10.1016/j.respol.2006.09.027>
- Leydesdorff, Loet; Ivanova, Inga; Meyer, Martin S.** (2019, in press). "The measurement of synergy in innovation systems: Redundancy generation in a Triple Helix of University-Industry-Government relations". In: W. Glänzel, H. Moed, U. Schmoch; M. Thelwall (eds.). *Springer handbook of science and technology indicators*. Heidelberg, etc.: Springer. ISBN: 978 3 030 02510 6
- Leydesdorff, Loet; Perevodchikov, Evgeniy; Uvarov, Alexander** (2015). "Measuring triple-helix synergy in the Russian innovation systems at regional, provincial, and national levels". *Journal of the Association for Information Science and Technology*, v. 66, n. 6, pp. 1229-1238.
<https://doi.org/10.1002/asi.23258>
- Leydesdorff, Loet; Porto-Gómez, Igono** (2019). "Measuring the expected synergy in Spanish regional and national systems of innovation". *Journal of technology transfer*, v. 44, n. 1, pp. 189-209.
<https://doi.org/10.1007/s10961-017-9618-4>
- Leydesdorff, Loet; Strand, Øivind** (2013). "The Swedish system of innovation: Regional synergies in a knowledge-based economy". *Journal of the American Society for Information Science and Technology*, v. 64, n. 9, pp. 1890-1902.
<https://doi.org/10.1002/asi.22895>
- Leydesdorff, Loet; Wagner, Caroline S.; Porto-Gómez, Igone; Comins, Jordan A.; Phillips, Fred** (in press). "Synergy in the knowledge base of U.S. innovation systems at national, state, and regional levels: The contributions of high-tech manufacturing and knowledge-intensive services". *Journal of the Association for Information Science and Technology*.
- Luhmann, Niklas** (1997). "Limits of steering". *Theory, culture & society*, v. 14, n. 1, pp. 41-57.
<https://doi.org/10.1177/026327697014001003>
- Lundvall, Bengt-Åke** (1988). "Innovation as an interactive process: from user-producer interaction to the national system of innovation". In: G. Dosi, C. Freeman, R. Nelson, G. Silverberg; L. Soete (eds.). *Technical change and economic theory* (pp. 349-369). London: Pinter. ISBN: 978 0 861878949
- Lundvall, Bengt-Åke** (ed.) (1992). *National systems of innovation*. London: Pinter. ISBN: 978 1 843318668

- Malerba, Franco** (1993). "The national system of innovation: Italy". In: R. R. Nelson (ed.). *National innovation systems: A comparative analysis* (pp. 230-259). Oxford University Press. ISBN: 978 0 195076172
- Mameli, Francesca; Faggian, Alessandra; McCann, Philip** (2009). "Employment growth in Italian local labour systems: Issues of model specification and sectoral aggregation". *Spatial economic analysis*, v. 3, n. 3, pp. 343-360.
<https://doi.org/10.1080/17421770802353030>
- McGill, William J.** (1954). "Multivariate information transmission". *Psychometrika*, v. 19, n. 2, pp. 97-116.
<https://doi.org/10.1007/BF02289159>
- Nelson, Richard R.** (ed.) (1993). *National innovation systems: A comparative analysis*. New York: Oxford University Press. ISBN: 978 0 195076172
- Nuvolari, Alessandro; Vasta, Michelangelo** (2015). "The ghost in the attic? The Italian national innovation system in historical perspective, 1861-2011". *Enterprise & society*, v. 16, n. 02, pp. 270-290.
<https://doi.org/10.1017/eso.2014.25>
- OECD.** (2009). *OECD Reviews of regional innovation: Piedmont, Italy*. Paris: OECD. ISBN: 978 92 64039162
- Oh, Deog-Seong; Phillips, Fred-Young; Park, Sehee; Lee, Eunghyun** (2016). "Innovation ecosystems: A critical examination". *Technovation*, v. 54, pp. 1-6.
<https://doi.org/10.1016/j.technovation.2016.02.004>
- Paci, Raffaele; Usai, Stefano** (1999). "Externalities, knowledge spillovers and the spatial distribution of innovation". *GeoJournal*, v. 49, n. 4, pp. 381-390.
<https://doi.org/10.1023/A:1007192313098>
- Petersen, Alexander M.; Rotolo, Daniele; Leydesdorff, Loet** (2016). "A Triple Helix model of medical innovations: Supply, demand, and technological capabilities in terms of Medical Subject Headings". *Research policy*, v. 45, n. 3, pp. 666-681.
<https://doi.org/10.1016/j.respol.2015.12.004>
- Prota, Francesco; Viesti, Gianfranco** (2013). *Senza cassa. Le politiche per lo sviluppo del Mezzogiorno dopo l'intervento straordinario*. Bologna: Il Mulino. ISBN: 978 88 15239808
- Pugh, Derek S.; Hickson, David J.; Hinings, C. Robert** (1969). "An empirical taxonomy of structures of work organizations". *Administrative science quarterly*, v. 14, n. 1, pp. 115-126.
- Rocha, Frederico** (1999). "Inter-firm technological cooperation: effects of absorptive capacity, firm-size and specialization". *Economics of innovation and new technology*, v. 8, n. 3, pp. 253-271.
<https://doi.org/10.1080/10438599900000011>
- Rolfo, Secondo; Calabrese, Giuseppe** (2006). "From national to regional approach in R&D policies: the case of Italy". *International journal of foresight and innovation policy*, v. 2, n. 3-4, pp. 345-362.
<https://doi.org/10.1504/IJFIP.2006.010408>
- Rotolo, Daniele; Rafols, Ismael; Hopkins, Michael M.; Leydesdorff, Loet** (2017). "Strategic intelligence on emerging technologies: Scientometric overlay mapping". *Journal of the Association for Information Science and Technology*, v. 68, n. 1, pp. 214-233.
<https://doi.org/10.1002/asi.23631>
- Shannon, Claude E.** (1948). "A mathematical theory of communication". *Bell System technical journal*, v. 27, n. 3, July and October, pp. 379-423 and 623-656.
<https://doi.org/10.1002/j.1538-7305.1948.tb01338.x>
- Storper, Michael** (1997). *The regional world – territorial development in a global economy*. New York: Guilford Press. ISBN: 978 1 572303157
- Storper, Michael; Kemeny, Thomas; Makarem, Naji; Osman, Taner** (2015). *The rise and fall of urban economies*. Stanford, CA: Stanford University Press. ISBN: 978 0 804789400
- Theil, Henri** (1972). *Statistical decomposition analysis*. Amsterdam / London: North-Holland. ISBN: 978 0 444103789
- Vernon, Raymond** (1979). "The product cycle hypothesis in a new international environment". *Oxford bulletin of economics and statistics*, v. 41, n. 4, pp. 255-267.
<https://doi.org/10.1111/j.1468-0084.1979.mp41004002.x>
- Yeung, Raymond W.** (2008). *Information theory and network coding*. New York, NY: Springer. ISBN: 978 0 387 79234 7



Más de 1.000 revistas a texto completo listas para **explorar**

MLA
International
Bibliography
with Full Text

Esta nueva base de datos creada por Modern Language Association (MLA) y EBSCO, combina el índice definitivo para el estudio del lenguaje, la literatura, la lingüística, la retórica y composición, el folclore y el cine con texto completo de más de 1.000 revistas, muchas de las más utilizadas en *MLA International Bibliography*

Solicite una
prueba gratuita

Para una prueba gratuita,
comuníquese con su
representante de EBSCO o visite:



EBSCO